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LIGHTHOUSE ENGINEERING AS DISPLAYED AT THE CENTENNIAL EXHIBITION.

By J. G. BARNARD, U. S. Army, Hon. Member of the Society.

As Chairman of Sub-committee on Lighthouses and Signals, organized for the object of aiding "in a proper representation of American engineering progress and practice at the Centennial Exposition, it now becomes my task to report on the exhibit of objects connected with above branches of engineering. It must be stated at the outset that Lighthouses and Signals being subjects *exclusively* of Government control, for which a Government organization—"The Lighthouse Board of the United States"—has been created, that board, of which the Secretary of the Treasury is *ex officio* the President, arranged and directed its own exhibit, leaving nothing for your Sub-committee to do.

A commission for this duty was appointed by the Lighthouse Board, consisting of Captain John L. Davis, U. S. N., member of the board; Brevet Brigadier General W. F. Raynolds, U. S. A., Engineer of the Fourth Lighthouse District; Commander G. B. White, U. S. N., Inspector of the Fourth Lighthouse District; and Lieutenant A. G. Paul, U. S. N.

Owing to the small amount of money available ($6,000), the exhibit could not be as complete as the board desired it should be. Through this cause the *engineering* branch of the exhibit suffered more than any other. No models or drawings could be made *expressly* for the Exhibition, and the commission was constrained to content itself with the exhibition of such models, drawings and photographs as were already in possession of the board. It so happened that the iron work for the superstructure to an iron lighthouse for a marine site, on the tubular plan was nearly ready for erection upon the already constructed tube base on the reef at the entrance of New Haven Harbor, called the *South West Ledge*, while another set of iron work exactly similar was in construction at Baltimore for a work on Ship John Shoal in Delaware Bay.

It was the desire of the board to exhibit by full sized model, or by temporary use of some actual construction, a complete lighthouse, embodying some important *engineering* model, such, for instance, as one of our great iron skeleton tower lighthouses. Want of money prevented carrying out this design, but advantage was taken of the existence of parts of intended iron lighthouse structures to make an exhibit, which, if but an imperfect realization of the idea, enabled the board at least to exhibit an actual lighthouse. A wooden cylindrical substructure representing so much of the really important (in an engineering point of view) tubular member of the South West Ledge lighthouse as appears above the water was made, and on this the *real* superstructure, comprising the keeper's dwelling and store rooms, surmounted by the lens with its lantern, was erected. The light was shown on the night of the 4th of July, and from that date was maintained until the close of the Exhibition, with the same regularity and under the same rules as if it had been an actual sea-coast light, the keeper residing in the structure. But the real engineering significance of the kind of construction of which this exhibit was the type was quite undeveloped, the *tubes* which form their principal member being specially designed for sub-aqueous sites covered by considerable depths of water. These engineering features will be alluded to in another place.

Passing by for the present all other objects, I come at once to the models exhibited. The following is a list (transcribed from the report to the Lighthouse Board of Lieutenant A. G. Paul, U. S. N.) :

CLASS I.

No. 1. Model of the caisson and coffer-dam used in building the foundation for Spectacle Reef Lighthouse, Straits of Mackinac.

No. 2. Model of Spectacle Reef Lighthouse at entrance to the Straits of Mackinac in Lake Huron.

No. 3. Model of Brandywine Shoal Lighthouse on Brandywine Shoal, Delaware Bay.

No. 4. Model of Coffins Patches (*i. e.*, Sombrero) Lighthouse. An iron pile structure on the Florida Reefs.

No. 5. Model of Sand Key Lighthouse, on a small sand and shell island in the Florida Reefs, 7¼ nautical miles from Key West, Fla. An iron pile light house 121 feet from base to focal plane.

No. 6. Model of lighthouse at Chicago, Ill. An iron tower on the north pier of Chicago Harbor, Lake Michigan.

No. 7. Minot's Ledge Lighthouse, on the outer Minot, Boston Bay.

No. 8. Model of cribwork for foundation of South West Pass Lighthouse, mouth of the Mississippi River.

Besides these models, pictorial views, litho or photographic, of the following works were exhibited (list copied from Lieutenant Paul's report) :

No.	1.	Currituck Beach	Lighthouse,	N. C.
"	2.	St. Augustine	do.	Fla.
"	3.	Race Rock	do.	Long Island Sound,
"	4.	Cleveland, Ohio,	do.	Lake Erie.
"	5.	Piedres Blancas	do.	California.
"	6.	Ship John Shoal	do.	Delaware River.
"	7.	Hunting Island	do.	S. C.
"	8.	Thimble Shoal	do.	Hampton Roads, Va.
"	9.	First-class lighthouse with steam fog signal.		
"	10.	Screw-pile river and harbor lighthouse.		
"	11.	Sand Key Lighthouse, Fla.		
"	12.	Alligator Reef	do.	"
"	13.	Pigeon Point	do.	California.
"	14.	Do. do.	do.	do.

No. 15. Craighill Channel Lighthouse (Front), Chesapeake Bay.
" 16. Do. do. do. (Rear) do.
" 17. Fort Sumpter do. S. C.
" 18. Lighthouse tender.
" 19. Cross Point Lighthouse, Lake Michigan.
" 20. Fowey Rocks. do. Fla.
" 21. Day Beacon, Flower Reef, Long Island Sound.
" 22. Minot's Ledge Lighthouse, Massachusetts Bay.
" 23. Penfield Reef do. Long Island Sound.
" 24. Spectacle Reef do. Lake Huron.
" 25. Foundation for Cross Ledge Lighthouse, Delaware Bay.
" 26. Do. do. do. do.
" 27. Do. do. do. do.
" 28. Tybee Island do. Ga.
" 29. Old Field Point do. Long Island Sound.
" 30. Fowey Rocks do. Fla.

" 31. A large map, 17 feet by 19 feet, showing on it each light under the jurisdiction of the Lighthouse Board of all classes; each class can be distinguished by a glance at the chart, the size of the red circular spot denoting the order and range of visibility. By the showing on this chart, the following list of the different orders can be seen :

First	46
Second	28
Third	67
Fourth	190
Fifth	125
Sixth	179
Stake*	280
Reflectors and Lightships	38
	953

* By the term "stake" is denoted a class of lights peculiar to the United States, and of recent introduction. They are for aiding the navigation on the Mississippi and its two principal tributaries, the Missouri and the Ohio, variability of the channels of which forbid permanent structures. They consist of a lantern suspended from a post or wooden scaffolding easily removable, and generally called a "stake," on the banks, the position of which may be shifted to correspond to the shifting of the channels. At date of last Annual Report of the Lighthouse Board for 1878, there were on the Ohio 244 "stakes" and 12 "floating" lights; on the Missouri, 34; on the Mississippi, above St. Louis, 155; below, 193; or 626 stake lights in all These "beacon-lights," says the report of the board, "continue to give great satisfaction to those interested in river navigation, and may now be regarded as indispensably necessary.

I proceed to describe the peculiar engineering features of the works represented by the models and pictures.

The lighthouse on Minot's Ledge is the most important *engineering* work that belongs to our lighthouse system; and indeed it ranks, by the engineering difficulties surmounted in its erection, and by the skill and science shown in the details of its construction among the chief of the great *sea-rock* lighthouses of the world.

"Minot's Rocks—or, as they are generally designated, 'the Minots'—lie off the southeastern *chop* of Boston Bay. . . . These rocks or ledges, with others in their immediate vicinity, are also known as the 'Cohasset Rocks,' and have been the terror of mariners for a long period of years; they have been, probably, the cause of a greater number of wrecks than any other reefs or ledges upon the coast, lying as they do at the very entrance to the second city of the United States in point of tonnage, and consequently where vessels are continually passing and repassing. The Minots are bare only at three-quarters ebb, and vessels bound in, with the wind heavy at northeast, are liable, if they fall to the leeward of Boston Light, to be driven upon these reefs. The rock selected for the site of the lighthouse is called the 'Outer Minot,' and is the most seaward of the group. At extreme low water an area of about 30 feet in diameter is exposed, and the highest point in the rock is about 3½ feet above the line of low water. It is very rare, however, that a surface greater than 25 feet in diameter is left bare by the sea. The rock is granite, with vertical seams of trap rising through it."

This work is one of peculiar engineering interest. The site had been occupied by an iron skeleton lighthouse, built (1848) by Captain W. H. Swift, of the United States Topographical Engineers, and carried away by the great storm of 14th, 15th, 16th, 17th of April, 1851. The history of this work, and of the catastrophe which befell it, is briefly given in the article, *Lighthouse Construction*, in Johnson's Cyclopedia.

The structure of which the model was exhibited succeeded the work just alluded to.

The difficulties of the work will be best appreciated from the following statement of the engineer:*

"It was a more difficult work of construction than either the Eddystone, the Bell Rock, or the Skerryvore, for the Eddystone was founded all above low water, part of its foundation being up to high-water level. The foundation of the Bell Rock was about 3 feet above low water, while

* In a succeeding number of the "Transactions" will be found the only connected "memoir" left by the engineer, the late Lieutenant-Colonel B. S. Alexander (Brevet Brigadier-General U. S. A.), on the history of the construction of this work.

the Skerryvore had its foundation above high-water level; whereas a good part of the foundation of the Minot's light was below low water. There had to be a combination of favorable circumstances to enable us to land on the Minot Rock at the beginning of that work—*a perfectly smooth sea, a dead calm, and low spring tides.* This only could happen about six times during any one lunation—three at full moon and three at the change. Frequently, one or the other of the necessary conditions would fail, and there were at times months, even in summer, when we could not land there at all. Our working *season* was from April 1 to September 15. Work was prosecuted with all possible diligence for more than three years before a single stone could be laid. *The* difficulty was to cut the foundation rock into the proper shape to receive the foundation stones, and then to lay these stones."

Both an elevation and a vertical section are given herewith. The shaft is purely conical, the limited bottom area forbidding the expansion required for the *tree-like* spread to the base—which is usual in European sea-rock lighthouses.

The structure is solid (around a central well) up to the level of the entrance-door. Above that there is a hollow cylindrical space, 14 feet in diameter, arched over at the level of the cornice. This space is divided into five stories by four iron floors. These five compartments, and a sixth, immediately under the lantern, constitute the keeper's rooms, store-rooms, etc. On Plate 12 is shown an elevation and vertical section of the tower, and also horizontal sections showing the "bond" of the stonework of the solid parts, also of the Eddystone, Bell Rock, Skerryvore and Wolf Rock towers. There is besides a plan of the Rock itself as prepared to receive the foundation stones, in which the numbers (with the plus or minus sign) indicate the *level* of the respective areas—*e. g.* (—1′ 3″) indicate 1 foot 3 inches *below* the *zero;* which zero, however, is itself 1′ 9″ above mean low water. The small black disks mark the holes for the iron shafts of the old structure. In these, continuous dowels were inserted, which ascended as far as the twelfth masonry course. In the horizontal section the gun-metal dowels are marked, by which each course of the solid part was secured to the one above or beneath. The courses of the shell above the solid part were each *joggled* by a middle annulus with the course above. The following details are given for reference.

The first blow was struck on the ledge Sunday morning at sunrise, July 1, 1855:

Hours worked on ledge in excavating foundation pit during 1855...	130 hours.
Hours worked on ledge in excavating foundation pit during 1856...	157 hours.
Hours worked on ledge in excavating or laying four stones during 1857....	130 h. 21 m.
Hours worked on ledge in excavating pit and in laying six courses during 1858..	208 hours.
Hours worked on ledge in laying twenty-six courses of stone during 1859....	377 hours.
	1,102 h. 21 m

No. tons of rough stone	3.514
No. tons of hammered stone....	2.367
No. stones in lighthouse....	1,079

The first stone was laid July 9, 1857; the lowest stone was laid July 11, 1858:

Whole height from bottom of lowest stone to top of pinnacle....	114′ 1″
Height of focal plane above lowest point....	96′ 1″
" " " mean high water....	84′ 7″
Diameter of third (or first full) course	30′
" top of twenty second course (solid part)....	23′ 6″

Observations made at Boston Lighthouse from June 7 to October 27, 1847, furnish the following results:

Rise of highest tide....	14 ft. 7 in.
Mean rise and fall of tides....	9 " 4 "
" " " spring tides....	10 " 8 "
" " " neap "	8 " 3 "

Besides the Minot's but one other specimen of that kind of lighthouse construction is offered by the Lighthouse Establishment of the United States. That one (Spectacle Reef), of which the model of the caisson and coffer dam used in building the foundation, and of the finished structure, were exhibited. This is not properly a "*sea*-rock" lighthouse, nor are the destructive agencies it has to encounter *sea-waves*, but chiefly *ice packs.*

It stands upon a reef in the northern part of Lake Huron, off the eastern end of the Straits of Mackinac. It is built upon the southern extremity of the most northerly of two shoals (limestone rock *in situ*, covered with a layer of about two feet in thickness of boulders), so situated with reference to each other as to suggest the name, "Spectacle

Reef." The least depth of water on the shoal is about 7 feet, but at the site selected for the lighthouse the rock was found at a depth of 11 feet. The nearest land is the southeasterly point of Bois Blanc Island, distant 10½ miles. The greatest exposure to waves is to the southeastward, from which direction the seas have a range of about 170 miles. Were there no other destructive agency, sufficient stability would have been easily secured. But, under certain meteorological conditions, currents having a velocity of from 2 to 3 miles per hour are developed here, which during the inclement season serve to move to and fro ice-fields which frequently have an area of thousands of acres and a thickness of as much as two feet. This ice, formed in fresh water, is of great solidity, and when moving in the mass, and with the velocity named, has a "living force" which is almost irresistible. The aim was to oppose to it a structure against which the impinging ice would be crushed and packed till it should ground upon the shoal itself, and form a barrier against subsequent action. To give some idea of the necessity for this, it may be mentioned that in the spring of 1875 the ice was piled up against the lighthouse to the height of 30 feet above the water, or 7 feet above the sill of the doorway, which is 23 feet above the lake, and when the keepers went to the station to exhibit the light (not in operation during the winter) they were able to obtain entrance to the tower only by first cutting a passage through the pile of ice referred to.

The first step was to surround the site of the proposed tower with a "pier of protection"—a crib-work (filled with ballast-stone) 92 feet square, enclosing an interior opening 48 feet square. This furnished a landing-stage and area for quarters for workmen, and secured still water in which to place the coffer-dam. The coffer-dam was cylindrical in form, 36 feet in diameter (exterior), and made of staves 4 inches thick, 6 inches wide, and 14 feet long. These staves, carefully jointed, were held together by three iron bands or hoops on the outside, and to enable it to withstand the pressure from the outside, when empty, the dam was braced and stayed in the strongest manner against a centre-post, the axis of which was coincident with the axis of the cylinder. The details by which the coffer-dam was built at the surface of the water, lowered, and, by then driving down individual staves wherever necessary, fitted to the irregular bottom and the joint calked, cannot here be given.* After ex-

* The engineer, Gen. O. M. Poe, a member of the Lighthouse Board, is engaged in preparing for publication by the Board a full account of this work.

hausting the water, levelling the bottom, and laying the first course, the annular space between it and the inside of the cylinder was filled with concrete, thus making an artificial bottom which was perfectly water-tight. The exterior of the tower (see Plate XIII) is a frustum of a cone, 32 feet in diameter at the base and 18 feet at the spring of the cornice 80 feet above the base. The cornice is 6 feet high, and the parapet 7 feet. The focal plane is 4 feet three inches above the top of the parapet. Hence the entire height of the masonry above the base is 93 feet, and of the focal plane 97 feet 3 inches. The base is 11 feet below the surface of the water, and the focal plane 86 feet 3 inches above the same surface. The tower is solid to a height of 34 feet. Above this it is hollow, and divided into five stories or rooms, each 14 feet in diameter. The courses (of uniform thickness of 2 feet) are *bonded* as represented; they are dowelled where solid and joggled where annular, very much as at Minot's, which work, indeed, served as a model,

The light was first exhibited June 1, 1874, work having been commenced May 1, 1870. The aggregate *working* time was really less than twenty-four months ; cost, $375,000.

The history of Mr. Alexander Mitchell's invention of the screw-pile, as also of its many subsequent uses for marine structures, are well known to professional engineers. As a means of lighthouse construction on sandy or soft sea bottoms, it was first designed, and the first construction of this kind—*the first screw-pile lighthouse*—was built by the inventor for the corporation of the Trinity House, on the Maplin Sand, at the mouth of the Thames. This interesting structure is fully described in Vol. VII., *Proceedings of the Institution of Civil Engineers.* Built in 1838, this work is still in perfect preservation. The iron tower on Minot's Ledge, though in other respects undistinguishable, was not a *screw-pile* structure, since its piles or angle-posts were set in holes drilled in the rock.

The first screw-pile light of the United States was erected by the late Col. Hartman Bache, U. S. E., near the mouth of Delaware Bay, 8 miles from the ocean, and very much exposed, on a shoal covered with 6 feet low water spring tides, but over which rise spring-tides 13½ feet and storm tides 18 feet. A lighthouse built here in 1827–28 by Mr. Strickland of Philadelphia (plan not known to writer) was very soon "demolished by action of the sea." A design was then proposed in the bureau of topographical engineers for a work built "on a mole of break-

water-stone." This was abandoned, because the superstructure, "being built upon breakwater stone thrown at random on the bottom, would by unequal settling be liable to fracture: and it was doubted whether heavy masses of masonry, raised upon such a base, ever proved entirely satisfactory;"* and some progress was made (1839) in the collection of stone and the building of a caisson, by means of which a masonry foundation was to be started from the bottom. This plan, too, was abandoned, and in the years 1847-50 the existing lighthouse was erected, which stands yet in good condition, though not without having required reinforcement to its ice-breaker. A peculiarity distinguishing it from all other screw-pile structures is due to its exposure to the powerful action of ice borne to and fro by the violent ebb or flood currents. The light-tower proper is surrounded by an *ice-breaker;* itself an iron screw-pile structure having no connection with the lighthouse, though the two *seem* to form one building. (See Plate XIV.) The *ice-breaker* has since this delineation been much enlarged, and its top floored over so as to form an esplanade.)

For the numerous sand-shoals in the great bays or off the southern coast of the U. S., which needed to be marked by lights, the screw-pile system, thus introduced, seemed especially applicable, and its extension has been very rapid; more than fifty such structures now exist, some of great magnitude and importance, but far the greater number for harbor or bay lights. Sand Key (1853), Carysfort (1857), Sombrero (1857), Alligator Reef (1873), all "first-order."

Models were exhibited of the Sombrero (Coffins Patches) and the Sand Key lighthouses; and a pictorial exhibit of that on Alligator Reef, which may be considered typical of the class. The nearest land, Indian Key, is 4 miles to the westward. A temporary platform was erected upon this site, supported on mangrove piles shod with iron, and driven five feet into the bottom in partially indurated coral rock. A small landing-wharf or jetty for receiving materials was also built in connection with this platform. The platform being completed, the nine heavy cast-iron foundation-disks were accurately placed at the centre and angles of the octagon, the surface of the coral rock being first smoothed and leveled for each disk. By an ingenious system of gauges the disks were set in their positions, with their proper relative

* A light has beed recently (1875) thus founded on a shoal—the "Cross Ledge"—15 miles above the Brandywine.

distances—a work of very great difficulty. The foundation-piles pass through the centres of the disks, and rest by shoulders upon them. These piles are of solid wrought iron, 26 feet long and 12 inches in diameter, and pointed at their lower ends, the upper ends being lathe-turned and cut off square. The pile-driver used in driving them carried a hammer of 2,000 pounds, which was hoisted by a portable steam-engine. The piles were kept accurately vertical during the driving by purchases attached to their heads. The penetration into the coral at each blow of the hammer with an average fall of 18 feet, varied from ½ inch to 1½ inches, and about 120 blows brought the shoulder of the piles into contact with the disks, giving them a depth in the coral limestone rock of 10 feet. The piles being driven, their tops were cut off to a horizontal plane 11 feet above the water, and the cast-iron sockets which fit on their heads were put in their places. The second series, consisting of nine solid wrought-iron pillars 10 inches in diameter, was inserted in these sockets, etc.

The work now in progress on Fowey Rock (shown in Plate XV), as it will be when completed, is presented on the extreme northern extremity of what is called the Florida Reef, is intended to be on the very reef itself; a substitute for the existing shore (Cape Florida) light. Having rather a more open exposure to the *ocean* waves (coming from N. E. from the Atlantic), to this work has been given a greater spread of base, and it is in other respects planned for enduring heavier strains than the first mentioned. The lower course of (vertical) foundation piles has, at the present date, June, 1877, been fixed on the site ; the superstructure will be added during the coming season.*

Although not included in the exhibit, the existing and designed actual screw-pile towers for Ship Shoal (Plate XVI), and Trinity Shoal should be noticed here.

Ship Shoal and Trinity Shoal, Gulf of Mexico, are submerged sand-banks, lying dangerously in the way of navigation between the mouth of the Mississippi and Galveston. A screw-pile structure was erected 1858–9, on the first, under the direction of the late W. H. Stevens, then an officer of engineers. Situated (lon. 91.04° W., lat. 28°55′) about five nautical miles from the nearest land, in 15 feet of water, this work has thus far resisted the force of the sea and of the wind (sometimes amounting to

* This lighthouse was completed and lighted June 15th, 1878.

hurricanes). Some trouble has been caused from the erosion of the sea bottom, and a covering of quarry stone is designed to be applied over a considerable area. A similar work on Trinity Shoal was commenced in 1873, but the preliminary staging which had been erected was carried away in a severe gale, and the work has not been resumed; a lighthouse (the *Timbalier*) in the sheltered waters of Timbalier Bay, 60 miles west of the Southwest Pass of the Mississippi, has been recently (1874) rebuilt on this model.

The Southwest Pass lighthouse (Plate XVII) is an instance in which iron skeleton towers are resorted to for important land sites where the soil offers no adequate support for a masonry structure. A model of the foundation grillage was exhibited. Plate XVII shows an elevation of this structure and its connection with the foundation. The two upper courses of grillage timber were omitted in the construction.

The soil, recent alluvial, made up of the sedimentary deposit of the river, is of clay, very fine sand, and vegetable matter; very yielding (*i. e.*, *plastic*, and in that sense "compressible"), and hence incapable, by itself, of bearing a heavy superstructure. But that the site is not *quite* so mere a quagmire as may be supposed, the erection on a grillage, in former years, of a brick tower is proof. This, it is true, has settled greatly,* but its abandonment had otherwise become imperative through encroachments of the sea. This beacon should be the prominent landmark of this portion of the Gulf, and a first-order light, 128 feet above sea-level, was designed. A commencement was made by driving wooden piles over an area 60 feet in diameter, 3½ feet apart, in rows of like distance, to a depth of fifty feet. Then another series of piles in the centre of each square thus formed. The first series was cut of at 2′ 6″ below low water, and the second series at 1′ 6″ below. A reticulation of grillage timbers was laid on the heads of the first series and carried up for four or more thicknesses, the intervals or free space being packed with concrete, then concrete alone, to make a thickness of about eight feet. On the surface of this were secured, or bolted, the iron socket-disks from which start the nine (eight external and one central) shafts of the skeleton. The light was first exhibited in the beginning of 1873, two or three years having been occupied in the construction.

* Besides great vertical settlement, the tower is said to have *leaned* 2⅛ feet. It must have been built between 1840 and 1850.

The lighthouse actually erected on the Exhibition grounds, as has been stated, had for its superstructure the iron work prepared for the S. W. Ledge, New Haven Harbor.

The accompanying Plate XVIII exhibits so much of the structure as appears above water.

The site is rock, submerged in eleven feet of water (low tide). A ring breakwater of quarry stone (rip-rap) was thrown about the site; the rock levelled by a layer of concrete, and the lower horizontal section of the cast iron tube set by aid of a diving bell, the separate sections of which were united into complete rings by bolting together the flanges.

The tubular foundation just described was designed by Major Geo. H. Elliot, when Engineer-Secretary of the Lighthouse Board,* for sites where the prevalence of ice would be inimical to iron-pile structures. The Craighill Channel (approach to the port of Baltimore) front light represents another of these structures, having, however a very different superstructure.

It is described as follows:

"The cast iron tube, between high and low water, and for at least 2 feet above and below the space included between those limits, is 2 inches thick, the other portions to be 1¼ inches thick. The tube consists of two parts, the lower portion, for a height of 12 feet, being in the form of a frustum of a cone 30 feet in diameter at the base, 24 at the top; the upper portion is a cylinder of the same diameter as the top of the frustum of the cone to which it is joined. The tubing is cast in sections, each section being divided into twenty-four parts, joined together through flanges by wrought iron bolts. The lower section of the tubing is bolted to a grillage or flooring consisting of four layers of timber each 12 inches thick, forming a caisson, which is sunk in position below the bottom of the bay by filling it with concrete. It was found that for a depth of 22 feet the soil is the softest kind of mud—so soft, in fact, that an ordinary pile on end would penetrate 20 feet under the action of its own weight. Below this, alternate thin layers of sand, mixtures of sand, mud and shell were found to a depth of 20 feet more, with no signs of a solid foundation within 60 feet of the water's surface. It was therefore determined to drive a cluster of piles, cut them off at a level of 27 feet

* A structure on this plan had been first erected by Col. (Bvt. Brig. Genl.) Duane, the Duxbury pier light, near Plymouth.

below the surface of the water, and lower the caisson on them by filling it with concrete ; and in order to prot ct the lighthouse from lateral vibration and the scour of the tides, to build a rip-rap wall of loose stones around it."

"A structure of the same kind, resting likewise upon piles driven into a sand and clay bottom, has been placed on Ship John Shoal, Delaware Bay, which, in external appearance, will be the same as the S. W. Ledge lighthouse. The manner of constructing and founding the tube of this work is thus described by the Engineer, Gen. W. F. Raynolds :

"The construction was in all respects according to the specifications, excepting that the wooden bottom of the iron caisson was given one foot greater diameter than called for. The shoal was dredged until we had about 17 feet at low tide (originally 8 feet). In this basin the piles called for were driven, each pile estimated capable of bearing 30 tons. A U shaped platform was built around the piles and a sheet piling guard opposite the opening; the side of platform opposite the guard was also faced with sheet piling, thus cutting off both ebb and flood tide, and making a still basin in which to work.

"A traveler or truss on wheels was thrown across between the arms of the U ; on this was placed a circular saw or vertical shaft run by steam, by which the piles were cut off 16 feet below the level of low tide. A mistake was made in suspending this saw by a wire rope, as the level of the saw was slightly changed by the twist, rendering it necessary to block up some of the piles nearly an inch to get the heads perfectly level.

"The difficulty in sinking the caisson was this : An ordinary tide rises 6 feet ; storm tides, 10 feet. Hence we had to make it secure in 26 feet of water, while on the bar over which it was to be carried there was only 10 feet. A wooden caisson was built on the projection of the bottom of the iron caission. Concrete was then placed in the iron caisson until the whole was drawing just 10 feet. Then after getting the caisson into position by letting water into the wooden caisson (between it and the iron), which did not take over ten minutes, it was sunk to 18 feet. It was floated into position at high tide, and the fall of the tide would have brought the bottom of caisson on the heads of the piles.

"The iron caisson was 24 feet in diameter. Inside of it a box was built 17 feet in diameter. The final sinking and securing was effected by filling this box with gravel, which was easily done between tides.

The outside caisson was held in position by vertical rods. It was taken away as soon as possible by unfastening these rods and making two vertical cuts through it with saws.

"I may add that the spaces between the piles were filled up with small stone to the level at which they were cut off, and after sinking, a spirit level on the top of the iron caisson, showed it was horizontal."

The light-towers of terra firma, even (if the site be elevated) for the most important lights, require only so much elevation as will prevent obscuration by surrounding objects, and in general present no features of engineering interest. If, however, the site be very low, a light of the first order, demanding an elevation of at least 150 feet, the structure appeals to the engineer not only for accurately calculated elements of stability, but for well-devised interior arrangements. One of the most recent of these structures, Body's Island lighthouse, N. C., was not represented at the Exposition (see Plate XIX). "A secure foundation was obtained by excavating until a bottom of hard, clear sand was reached at 7 feet below the surface. On this was laid a grillage of timbers 6" by 12", placed at right angles to each other in two layers; then followed one course of dimension stone 18" thick; over this coursed rubble laid in large blocks, thorougly breaking joints, and all grouted with 1 part Portland cement and 2 of sharp sand. From this foundation rises the base of the tower, the frustum of an octagonal pyramid with plinth and cornice. The interior 'well' of the tower is lighted by five windows. Access to the watch-room is had by eight sets of spiral stairways, the first seven of which make half the revolution of a spire, the eighth an entire revolution. These stairways are not attached to the tower walls, but are supported by the landings—semi-circular iron plates resting on I-beams and a corbelling projecting from the interior face of the tower. There is a hand-rail on each side, and the entire system of stairs belonging to each flight is kept rigid by making the carriers of such a form that each baluster firmly bolts together three contiguous ones." The arrangement of the stairs, by which the encumbrance of a central shaft containing a winding stair is avoided, the interior better lighted, and room gained, is an improvement introduced by Major Elliot.

The height of tower from base to focal plane is 150 feet. Plate XIX exhibits an elevation, vertical section, and several horizontal sections.

The St. Augustine (Fla.) light, of which there was a pictorial exhibit, is of identical construction, and has the same height of tower.

A pictorial exhibit was presented of the lighthouse on Hunting Island, S. C. This represents a peculiar case.

The north point of the island is undergoing abrasion by wave action. The objects the light should subserve fixed the location *within* the possible future range of this abrasion. Hence it was determined to make a tower which can be taken down and removed in case of necessity, though the contingency was not deemed probable. The lighthouse is shown in Plate XX. "The 12-hundredweight iron panels of each horizontal section were cast of exactly the same size, so that each might occupy any position in its own section. The panels of the shell vary in thickness from 1½ inches (lowest section) to ¾ inch (highest). The flanges serving to connect the several tiers of plates and the plates of each tier with each other are smooth and true-planed surfaces; the holes in the flanges are drilled, and the bolts turned to neatly fit them. The base of the first tier of panels consists of a flange 3 feet wide. Of this flange the width of 1 foot 4 inches extends beyond the outside of the tower; this part contains the holes for the foundation bolts, which are strengthened by bosses and vertical knees extending upward to the top of castings. The top flange is 6 inches by 1¾ inches; the lower flange of the second section is 1 foot 2 inches wide. The top flange of this tier and the flanges of the third section are 6 inches by 1¾ inches. The flanges of succeeding sections are similar, with some slight variation of dimensions. The side flanges correspond in size with the top flange of each panel. All the horizontal flanges have strengthening knees on each panel, 2 feet high and 1½ inches thick, at equal distances apart. An interior lining of brick, 9 inches thick, is built in between the lower flanges. The whole structure rests on a concrete foundation 8 feet thick, to which the lower iron section is secured by 36 anchor bolts built into the concrete.

The Race Rock lighthouse (Plate XXI) presents a peculiar aspect of the problem of subaqueous foundations.

"The Race" is applied to what may be called the eastern water-gate to Long Island Sound, lying between the N. E. extremity of Long Island and Fisher's Island (off New London, Conn.). Little Gull Island, the Long Island *gate-post*, is marked by a light. The other gate-post (to maintain the simile) was Race Rock, three-fourths of a mile from the

S. W. point of Fisher's Island, an isolated submerged rock, or rather a huge boulder, surrounded by depths of 12 or 15 feet, low water, with 3 feet additional at high water. The tides (hence "The Race") flow with excessive violence, with but brief intervals of slack water. From the E. and S. E. the ocean wave finds no barrier save Block Island, and, therefore, violent wave-action was apprehended; moreover, *ice* from New London harbor and the marginal waters of the Sound is to be feared in winter. Hence, to form a rip-rap embankment (*a pierre perdue*) of oval form, 100 by 150 feet, well protected on its margins by blocks of eight or ten tons weight, was decided upon as the first step. This would be not only an immediate means of getting at the site, but a future protection against wave and ice violence. The interior of this embankment was then removed (better to have left it vacant in the first place), and the foundation of concrete (retained in form externally by circular bands of sheet iron each about two feet high) was brought up from the bottom by aid of the diver, who first accurately placed each successive band. It should be remarked that the natural bottom is of boulders compacted with gravel and sand, and therefore very firm.

In other cases of interaqueous construction, where the depth is not great, a simple *rip-rap* foundation of quarry stone is resorted to. The Penfield Reef (off Black Rock harbor, Conn.), of which a pictorial exhibit was made, is a case of this kind (see Plate XXII).

A more important engineering structure of this kind is exhibited by the work now in construction* on Stratford Shoal, Long Island Sound. In this case the rip-rap was thrown as a *ring*, the interior of the ring filled up with concrete laid subaqueously on the surface of the shoal, which was very compact gravel, covered with about six feet of water, low tide.

Plate XXII shows the general appearance of these structures.

In what precedes, only types of lighthouse construction involving features of engineering interest are presented. However interesting to those for whom the sea-coast illumination is the special duty, to the engineer in general the peculiarities of ordinary lighthouse construction are matters of little interest, and are not dwelt upon in this report.

For the same reason I pass over entirely the subject of *illumination*, and also that of *signals*. Both these subjects in their connection with

* Completed and lighted in 1877.

the Centennial Exposition have been fully reported upon to the Lighthouse Board by Lieut. A. G. Paul, United States Navy.* I therefore turn to the exhibits of foreign countries, and take the liberty of making a brief extract from Lieut. Paul's MSS. report:

"France appears to be the only government that has made any attempt to exhibit a complete condition of its lighthouse system, and, under the direction of the Ministry of Public Works, has put up a building, a large portion of which is devoted to lighthouse matters.

"Commencing with the country itself, we find that on the 1st of January, 1876, France (not including Algeria) had three hundred and seventy-nine lighthouses in position and working. This includes lightships and floating lights:

First order	45
Second "	6
Third "	31
Fourth "	33
Fifth "	254
Lightships and floating lights	10
	379

"In connection with these data several large books were sent over containing photographs of nearly all of the most important lighthouses; also a large chart showing the lights and the radius of visibility on it; and several books of reference, and some documents."

The following exhibits were made by model or by pictorial representation:

State of lighting and beaconing on the coasts of France.
Lighthouse of Cape Spartel (Morrocco).
" New Caledonia.
" les Roches-Douvres.
" les Héaux de Bréhat.
" la Croix.
" Creac'h (Island of Ouessant).
" le Four.

* The subject of LIGHTHOUSE ILLUMINATION forms too the theme of an article in the third volume of Johnson's Cyclopedia; by Maj. P. C. Hains, Engineer-Secretary to the Lighthouse Board of the United States.

Lighthouse of la Banche.
" les Barges.
" la Palmyre.
" Saint Pierre de Royan.
" Ar-Men.
Turret and candelabrum for port-lights.
Apparatus for lighting.
Lamps and appliances for the use of mineral oil in lighthouses.
Buoys and beacons.

These structures are described in a general way in the report of Lieut. Paul, and I shall only mention three of them, the more especially as drawings cannot be presented, except in one case. Availing myself of the printed "notices of the models, charts and drawings relating to the works of the 'Ponts et Chaussées and the Mines,' which, in English and in French, were furnished to professional visitors to the special exposition of the Ministry of Public Works."

The lighthouse of the Héaux de Bréhat is situated about three miles (five kilos) seaward from the most northerly point of the peninsular of Brittany, France. The character of its site is not described; but the work is reckoned among the "sea-rock lighthouses" of the world, which, besides the Minot's (American), may be thus enumerated: "Eddystone," "Bell Rock," "Skerryvore," "Bishop Rock" (1853), off the Scilly Islands, "The Small's Rocks," entrance to Bristol Channel, "Hanois Rocks" (1862), Island of Alderney, "Barges d'Olonne" (1861), west coast of France, "Wolf's Rock" (1869), off Land's End, England, and "Alguada Reef" (1865), Bay of Bengal, and the "Great" and "Little Basses Light," off the Island of Ceylon.

"The Héaux de Bréhat consists of a cylindrical tower 47 metres 40 inches in height from the arris of the base to the foot of the lantern, and is divided into two principal parts. The lower part is intended to support the strongest pressure, and to resist the most violent shocks of the waves; it is, therefore, constructed with great solidity. With this view the profile of the exterior follows a concave elliptic curve, which gives a large projection to the base; it is 18 metres in height, 13 metres 70 inches diameter at the base, and 8 metres 60 inches at the top, and the masonry is solid up to 1 metre above the highest tides.

"The auxiliary works were established on the Island of Bréhat, about ten kilometres from the rock, in order to take advantage of the

facilities for embarking materials, and of the favorable currents of ebb-tide, which tend directly from the island to the site of the lighthouse. Each course was dressed and accurately fitted together before its embarkation, and was afterwards landed at its destination on the rock, and carried to the tower by a series of cranes which passed the stones from one to another.

"Notwithstanding the violence of the shocks to which the lighthouse of Bréhat is exposed, it was not deemed necessary to have recourse to the means employed in similar cases to ensure the solidarity of all the stones of the edifice; but each course of the basement was divided into a certain number of great key-stones, each of which was fastened to the underlying parts by four granite plugs, let into the two adjacent courses, and placed at the angles of the compartment.

The lighthouse "des Barges" (*Phare des Barges*), is 2,100 metres from the coast, and is situated on the west of les Sables-d'Olonne, on the plateau of the great Barge d'Olonne (about 50 miles N.E. of La Rochelle), which is about 600 metres in length by 300 metres in breadth, and is entirely under water, with the exception of a few points emerging here and there in isolated groups.

The cylindrical tower is 24.81 metres in height above the rock, not including the turret of 2 metres. It is solid, and has elliptic facings up to 4 metres above the highest tides, or 8.50 metres above the rock, where the hollow part commences. The basement is 12 metres in diameter at the base, and 6.50 metres at the upper part. The hollow part is 16.31 metres in height, and 3.50 metres interior diameter; and the walls are 1.50 metres in thickness at the base, and 0.77 metres at the top, which constitutes a diminution of 0.045 per metre.

"At the 'Barges' lighthouse the tide currents are not very strong, but the violence of the sea is such that the spray sometimes rises to a height of more than 30 metres, and falls on the cupola. This reason dictated the expediency of so large an extent of basement, also its execution in solid masonry with facings of dressed granite, fastened by tenons and mortises.

"The entrance door, to which access is gained by a ladder let into the masonry, is placed 4 metres above the highest tides. At this level commences the hollow tower, the walls of which are entirely in roughly dressed granite. It is divided by brick vaults into five stories, connected

by stairs; in stone for the lower story, and in cast iron for the others. A double cincture in bronze consolidates the tower from the upper vault.

"The foundations presented very great difficulties. It was not found practicable to place the edifice on the point most elevated and most convenient for approach, as in that place the rocks were detached and full of fissures. This circumstance compelled the adoption of a site most exposed to the sea, and of which the average level was only 0.50 metres above the low spring tides, and 0.80 below low neap tides. The irregularities of the surface, and the inclined veins that it presented, led to the first course of the facing being let 0.25 metres to 0.30 metres into the rock, in order to prevent sliding. Two seasons were required to accomplish the levelling—those of 1857 and 1858—at the same time it ought to be mentioned that the rock is of extremely hard granite, so that not more than twelve stonecutters could be employed at once, and that the number of actual working hours was only thirty-eight in 1857, and forty-five in 1858."

"The necessity of protection from the waves was recognized from the commencement of the works, and for this purpose two jetties were constructed, one of which is 75 metres in length and 3 metres in breadth, with the top made flush with the level of high neap tides.

"The stones of the first four courses were landed and set by means of temporary appliances, consisting of a landing crane let into a post fastened to the lighthouse, and a setting crane, moveable on a circular plate fixed in the central stonework."

"In the month of July, 1859, more powerful apparatus was put up, consisting of a safety top and lifting shears, which served to raise the stonework of the basement to the level of high neap tides; but in the month of October following, the whole was carried away by a tempest of extraordinary violence."

* * * * * * * * * *

"All the masonry, except one part of the interior of the solid basement, was executed in Portland cement mortar, in the proportion of 1 part sand to 1 of cement for the dressed stones, and 2 of sand to 1 of cement for the rough stones and bricks. The filling in of part of the basement, below the level of the highest tides, was effected with rapidly setting cement mortar from the Isle of Ré, in the proportion of 1 part sand to 1 of cement.

"The works were commenced in 1857, and terminated in 1861. During these five seasons the workmen were able to land 346 times, and in all, to work at the lighthouse 1,960 hours, and at the jetties 308 hours.

"The total cost amounted to 450,000 francs, of which sum nearly 80,000 francs were for accessory works."

A still more interesting engineering construction is that of the "Phare d'Ar-Men." The rock called Ar-Men, but 5 feet above the extreme low tide (which here rises — feet), is a part of a reef (Chaussée de Sein) stretching seaward 8 miles from the Isle of Sein, 20 miles S. of the port of Brest (France). The Chaussée de Sein had long maintained a sad celebrity amongst nautical men. "To anchor a floating light at its extremity had been recognized to be impossible, owing to the great depth of water and to the bottom being thickly studded with rocks. An iron structure was considered impracticable, since the boring of holes (of 0.18 metres or 0.20 metres in diameter) for receiving the posts would be one of the most tedious and difficult operations. Moreover, it was feared, owing to the principal planes of rock-cleavage being vertical, that the structure would not resist the shocks it would be subjected to; besides, it would be almost impossible to land the cumbrous pieces of the iron framing." The dimensions of the rock were ascertained to be 7 or 8 metres in breadth by 12 to 15 metres in length at the the level of ebb tides; the surface was very unequal, and divided by profound fissures. The surface descended gradually on the western side, but almost perpendicularly on the eastern. "The following mode of construction was therefore decided upon, viz., to bore holes 30 centimetres in depth and 1 metre apart all over the site, and other holes outside this limit, in order to hold the ring-bolts necessary for craft coming alongside, and to fasten lashings. The object of the first set of holes was to receive wrought iron gudgeons, to fix the masonry to the rock, and to make the construction itself serve to bind the different parts and fissures, and thus consolidated a base the precarious nature of which gave rise to some misgivings. It was proposed that in additon to these gudgeons others should be added, and strong iron chains introduced horizontally into the masonry as it rose, to prevent any possible disjunction.

The services of the fishermen of the Isle of Sein were resorted to for boring the holes. "Two men from each boat landed on the rock, and, provided with their cork belts, lay down upon it, holding on with one

hand and using the jumper or hammer with the other ; they worked with feverish activity, the waves constantly breaking over them. * * * At the close of the season seven landings had been effected, and eight hours of work accomplished, during which fifteen holes had been bored in the highest parts of the rock.
* * * * In the following year sixteen landings were effected, eighteen hours of work accomplished, forty new holes bored ; and they even succeeded in partially levelling and preparing the work for the first course of masonry. The construction, properly so called, was undertaken in 1869. The galvanized wrought iron gudgeons, 0.06 metre square and 1 metre in length, were fixed in the holes, and the masonry was commenced with small undressed stone and Parker-Medina cement. In fact, a cement of the most rapidly hardening character was essential, for the work was carried on in the midst of waves breaking over the rock, and which sometimes wrenched from the hand of the workman the stone he was about to lay. * * * * When a landing was practicable, the stones and small bags of cement were landed by hand, and care was taken to dress the surface of the masonry before commencing a new course. At the close of the season of 1869, 25 cubic metres of masonry had been executed, and these were found intact the following year." At the date of the account quoted the masonry was raised 2.60 metres above the highest tides. "The success of the undertaking may therefore be looked upon as assured, and at this stage the work may be expected to advance more rapidly."

From the foregoing, the Phare d'Ar-Men is *sui generis* among sea-rock "lighthouses;" it is the only one in which, instead of massive blocks dowelled and dovetailed into cohesive continuity, small undressed stones (*petits moellons bruts*) have, through necessity, been made to serve.

Through the kindness of M. Lavoinne, Engineer of Ponts et Chausées and Delegate of the Ministry of Public Works to the Centennial Exhibition, I was furnished with the printed "*Notices sur les Dessins*," &c., there exhibited, and from which the above is taken, with a drawing showing the progress and state of the work up to the close of the year 1875 ; but feeling a great interest in this remarkable work, I am able, through the kindness of the Minister of the United States, the Hon. E. B. Washburne, and the courtesy of the French Ministry of Public Works, to present (Plate XXIII) a drawing showing the yearly progress

of the work to the close of the year, 1876, and the table herewith, which gives a summary of the work yearly executed, with cost, &c.

Years.	Number of		Volume of Masonry executed.			Expenditure for the year.	Average Cost of a Cubic Metre.
	Landings.	Hours passed on rock.	Per year.	Per landing.	Per hour.		
						Francs.	Francs.
1867..........	7	8				8,000	
1868..........	16	18				21,000	
		h. m.	m. c.	m. c.	m. c.		
1869..........	24	42.10	25.05	1.04	0.60	25,000	998
1870..........	8	18.05	11.55	1.44	0.64	26,336	2,289
1871..........	12	22.10	23.40	1.95	1.05	17 000	721
1872..........	13	34.20	54.55	4.20	1.62	40,000	727
1873..........	6	15.25	22.00	3.67	1.43	62,000	2,818
1874..........	18	60.10	115.30	6.41	1.91	71,800	623
1875..........	23	110.55	203.00	8.80	1.82	76,000	375
1876.....	23	162.45	128.00	5.56	0.78	80,000	625
		h. m.	m. c.	m. c.	m. c.		
Totals or Averages.....	127	466.0	582.85	4.59	1.25	429,136	733

"In the year 1876 only the month of July proved favorable; having been scarcely so previously, and permitting only 19 hours' work in all August and September. Nevertheless 162¾ hours of work were attained; an amount greater than that of any previous year. The sea, during a greater part of the winter was unusually rough on this coast; but causing not the slightest damage to the masonry."

Although no foreign nation except France represented her light house construction at the Exhibition, yet in an *engineering* point of view we need but a few additions, and those from English models, to make our review of the light house engineering tolerably complete.

The Eddystone, well known to all engineers, was the forerunner of the subsequent sea-rock lighthouses. Its more immediate successors—the Bell Rock and the Skerryvore—are described in works easily accessible to professional engineers. The Wolf Rock (off Land's End), described by Major George H. Elliot ("European Lighthouse Establish-

ments, 1873") as "perhaps the most elaborate and difficult of erection" on the British coast, as likewise the most recent, is on a rock 17 feet above low water, but submerged at high tide (which rises 19 feet), and of which the area scarcely exceeds the base of the tower; while the immediately surrounding depths reach 20 fathoms. The tower is 41 feet 8 inches diameter at base, 116 feet high, and solid from base to a height of 39 feet, or to the door of the lighthouse. The thickness of the walls at the doorway is 7 feet 9½ inches, and at the top, which is 17 feet in diameter, it is 2 feet. The shaft is a concave eliptical frustum, the generating curve of which has a major axis of 236 feet and a minor axis of 40 feet. "The stones are laid in off-sets to the level of 40 feet above the rock, with a view of breaking the sea, and above that height the surface is smoothly cut. Each face-stone is dovetailed vertically and horizontally into the adjoining stones, and each stone is bolted to the course below it by two 2-inch bolts—of yellow metal for the exterior and galvanized steel for the interior stones. The dovetailing was adopted not only for increase of strength, but to prevent displacement by the sea during construction, before the superincumbent weight of the additional courses could be obtained, and to protect the cement mortar of the joints from being washed out before it could be set."

The Bishop Rock Lighthouse, the construction of which preceded Wolf Rock, and which, like the Minot's, succeeded a storm-destroyed (though incompleted) iron pile structure, is mentioned by Findlay (*Lighthouses of the World*) as "probably the most exposed lighthouse in the world." The force of the waves is supposd to surpass even the measure registered at Skerrymore, *i. e.*, 6 000 pounds per square foot. "On January 30, 1860, a storm-wave shook this tower, and tore away the bell, weighing 3 hundredweight, from its support at the top of the tower, more than 100 feet above the sea. * * * Therefore, if these sea-beaten towers were not at least equal in weight to a solid block of granite of 60 or more feet in height, they would not be able to withstand the waves." In its construction it resembles very closely the Wolf Rock. From its tower beamed upon the fog-beshrouded steamer "Schiller," already upon the fatal rocks, the too late warning.

Two recent engineering structures of the same kind deserve the attention of engineers. A brief description of them will conclude my very general review of lighthouse engineering as directly or indirectly presented to us at the Centennial Exhibition.

On the Great and Little Bassas (or Bosses) Rocks, lying off the S. E. coast of Ceylon, in the direct path of vessels plying between the Suez Canal and ports of India, China, Japan, &c,, the Trinity House Corporation has constructed two lighthouses. The former (December, 1876) is completed and the latter nearly so. "The Great Bassas rock is about 6 feet above mean water-level, and the Little Bassas is only awash at low water, and is seven miles from the shore. These reefs, which are composed of hard red sandstone, are exposed to the full fury of the sea during the N. E. and S. W. monsoons, so that the days available for working are few, and these are almost exclusively during the prevalence of the N. E. monsoon, which commences in November and terminates in April; and even of this short period only half of it can be relied upon as safe for working. The towers are built of Scotch granite, the blocks of which were fitted together in the quarries before shipment. The blocks forming the walls and floors of both lighthouses are dovetailed together, both vertically and horizontally, upon the system adopted by Mr. Douglass in the Wolf Rock and Hanois Lighthouses." To land the stone "a strong mast 45 feet high, and supported by chain-guys, was shipped into the rock in a vertical position, and from this was supported a derrick which could be swung over towards the tower by means of a chain and a crab. The steamer was moored at a distance of 180 feet from and parallel to the rock, and the blocks of granite contained in the hold were ranged on two tiers of rollers, so as to facilitate their being brought under the hatchway, where an iron lifting, working in guides. conveyed them to the level of the deck." One barrel of the forward winch lifted the stone to the deck and deposited it on rollers in readiness to go out of the gangway. To one barrel of the after winch was attached the end of a half-inch chain, which passed first through a leading block at the gangway, then through another at the foot of the derrick, through a pulley at its top, and from thence through a block attached to the stone, and back to the head of the derrick, where it was made fast. For easing off the stone and to keep it in check, there was attached to it a second chain, the further end of which was coiled on the second barrel of the forward winch, which was controlled by a powerful brake. In landing a stone the aft steam winch was started, and, as the stone went over the side, the controlling chain was eased away by the brake until the stone entered the water, when it was gradually "paid" away as the after winch worked the stone ashore. The stone on reaching

the shore was swung by the derrick towards the tower, and lowered into its place. When the building rose to a height too great for the derrick to work, a steam winch was fixed upon the rock for hoisting the granite blocks to the top of the tower.

"By the very ingenious contrivance by which the stones were conveyed from the ship to the rock below the surface of the water they were out of the influence of the wind, and at the same time more than two-fifths of their weight was taken off, due to the difference between the specific gravities of granite and water. As these two lighthouses are but 20 miles apart, and very similarly situated, it was of the utmost importance to prevent the one being mistaken for the other either by day or night. Hence, a difference in the forms of the heads of the two towers, and also a difference in their lights. The Great Bassas light is distinguished at night by giving red flashes at intervals of 45 seconds, the duration of each flash being about 7 seconds, and that of the eclipses about 38 seconds." The illuminating apparatus of the Little Bassas Lighthouse is of a novel character, being upon the very beautiful "group-flashing" system of Dr. Hopkinson, whereby flashes in groups of two or more are given in quick succession, instead of single flashes at stated intervals of time.

A more detailed account of these important works will be found in "Engineering," October 27, 1876.

It should be stated that through the courtesy of the proprietors of Johnson's Cyclopedia, I have been permitted to transcribe from my own previously prepared article, "LIGHTHOUSE CONSTRUCTION," accounts of many of the works herein mentioned, and have been thus spared a double labor.

The following authorities may be consulted :

A Narrative of the Eddystone Lighthouse, &c., &c., by John Smeaton, London, 1797.

An Account of the Bell Rock Lighthouse, &c., &c., by Robert Stephenson, Ed. 1824, with a historical view of institution and progress of the Northern (or Scottish) lighthouses.

Account of the Skerryvore Lighthouse, with Notes on the Illumination of Lighthouses, by Alan Stephenson, London, 1848.

Article "Lighthouse," by Alan Stephenson, Encyc. Brittanica; Articles "Lighthouse Construction" and "Lighthouse Illumination," Johnson's New Universal Cyclopedia; "Report of the Officers consti-

tuting the Lighthouse Board," &c., 1852 (Ex. Doc., Senate, No. 28, $^{32}_{1}$); "Documents relating to Lighthouses, 1789 to 1871," by the U. S, Lighthouse Establishment, Washington, 1871; Extracts from "British Lighthouse Reports," by do. do., Washington, 1871; "European Lighthouse Systems," by Major Geo. H. Elliot (Ex. Doc., Senate, No. 54, $^{43}_{1}$); "Memoir upon the Illumination and Beaconage of the Coasts of France," translated from the French of M. Reynaud, Director, &c., by Colonel P. C. Hains, Engineer Secretary U. S. Lighthouse Board;" and list of authorities at end of article "Lighthouse," Encyc. Brittanica.

The Illustrations which follow are :—

Plate No.	XII.	Minot's Ledge Lighthouse, with Comparative Sections of other Sea Rock Lighthouses.	
do.	XIII.	Spectacle Reef Lighthouse.	
do.	XIV.	Brandywine Shoal	do.
do.	XV.	Fowey Rocks	do.
do.	XVI.	Ship Shoal	do.
do.	XVII.	Southwest Pass	do.
do.	XVIII.	Southwest Ledge	do.
do.	XIX,	Body Island	do.
do.	XX.	Hunting Island	do.
do.	XXI.	Race Rock	do.
do.	XXII.	Penfield Reef	do.
do.	XXIII.	Phare d'Ar-Men.	